Yield Advantage and Economic Benefit of Maize Basil Intercropping under Different Spatial Arrangements and Nitrogen Rates

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In areas where there is land shortage, crop intensification through intercropping major crops with high value crops is very crucial. Hence, a study was conducted during 2012 on Kombolcha ATVET College farm to evaluate effect of different nitrogen (N) rates (0, 92, 128 and 164 kg N ha\(^{-1}\)) and spatial arrangements (sole maize/basil, 1:1, 1:2 and 1:3 row ratios) on productivity and economic benefits of maize basil intercropping. The experiment was laid out in randomized complete block design with three replications. The result showed that cropping systems significantly affected growth and yield attributes of component crops. Each row arrangement showed higher productivity over sole planting of component crops. The highest values of land equivalent ratio (9.80), area time equivalent ratio (1.62) and monetary value index (11373.44) were obtained from 1:1 row arrangement. Maximum significant values of grain yield in maize (32.82 q ha\(^{-1}\)) and herbal yield in basil (263.25 kg ha\(^{-1}\)) resulted from application of 128 kg N ha\(^{-1}\). However, the interaction effect of fertilizer and cropping pattern was not significant on growth, yield attributes and yield of component crops. Economic analysis of fertilizer treatment showed that maximum net benefit (21971 ETB ha\(^{-1}\)) and marginal rate of return (3119.03%) at the rate of 128 kg N ha\(^{-1}\). Accordingly, it can be confirmed that intercropping maize with basil at 1:1 row arrangement with application of 128 kg N ha\(^{-1}\) could provide farmers with the best yield advantage and income over sole planting of component crops.

Key words: Maize, Basil, spatial arrangement, LER, ATER, MAI, marginal rate of return.

INTRODUCTION

In this study area, basil (spice crop) is cultivated around boarder of main crops fields (Teff, sorghum and maize) and home garden for its herbal yield (leaves and inflorescence) which has high demand on local market. With increasing pressures on agricultural land arisen out of population growth, farmers have to explore new ways to intensify production per unit area of land (Usmanikhai et al., 2012). Intercropping is growing of two or more crops simultaneously on the same field which can intensify crop both in time and space dimensions to raise production per unit area by increasing the plant population. It offers the possibility of yield advantage relative to sole cropping through yield stability and improved yield and thus providing diversified needs of small farmers, stability of yield over different seasons, better control of weeds, insect pests and diseases as well as control of soil erosion (Willey, 1979). Intercropping of maize with basil was also reported to successfully in reduce weeds biomass and density (Bagheri et al., 2014). On the other hand, one of the disadvantages of intercropping is reduction in yield of component crops due to competition. The extent of competition-induced yield loss in intercropping is likely to depend on the special arrangement of the component crops (Undies et al., 2012).

In Ethiopia low soil fertility is one of the factors limiting the productivity of crops (Berga et al., 1994). This is resulted from removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmland and lack of proper crop rotation program (Tamirie, 1982). Therefore, this study was initiated with the objective to evaluate the effect of
Table 1: Texture and selected chemical properties of soil of the experimental site

<table>
<thead>
<tr>
<th>Particle size distribution (%)</th>
<th>Textural class</th>
<th>pH (H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand 15.1</td>
<td>Clay 26.8</td>
<td>Silt 58.1</td>
</tr>
<tr>
<td>EC (dSm⁻¹) 0.25</td>
<td>OM (%) 2.35</td>
<td>Total N (%) 0.12</td>
</tr>
</tbody>
</table>

different nitrogen (N) rates and spatial arrangements on productivity and economic benefits of maize basil intercropping.

MATERIALS AND METHODS

Description of the study area

A field experiment was conducted on Kombolcha Agricultural College farm (11° 06' N, 39° 45'E), in South Wollo Zone of the Amhara Region. The area is located at an altitude of 1800 m with the annual rainfall of 1029 mm.

Treatments and experimental design

Local variety basil and improved variety of maize (Melkasa 2) were used as test crops. Sole basil was planted at 30cm x 10cm and intercropped with maize which was planted at 80cm x 25cm. The treatments consisted of four levels of cropping system: sole maize/sole basil, one row of maize alternating with one row of basil (1:1), one row of maize alternating with two rows of basil (1:2), one row of maize alternating with three rows of basil and four levels nitrogen; 0, 92, 128, 164 N kg ha⁻¹ arranged in randomized complete block design with three replications. 46 P₂O₅ kg ha⁻¹ was used uniformly applied to each plot. TSP and Urea were used as source of P₂O₅ and N, respectively. All phosphorus and half of nitrogen rates were applied at planting time and the remaining half levels of N at knee height of maize crop. Data were collected on plant height (cm), number of cobs per plant, number of kernels rows per cob, number of kernels per row, thousand seed weight (g), biological yield (q ha⁻¹) and seed yield (q ha⁻¹) for maize whereas for basil on plant height (cm), number of branches, biological yield (kg ha⁻¹) and herbal yield (kg ha⁻¹). Analysis of variance was used to test the significance of treatment effects using the computer program SAS 9.1.3. Least Significant Difference (LSD) Test was used to compare treatment means.

Land equivalent ratio (LER) and Area time equivalent ratio (ATER) were determined using formula defined by Willey (1991) and Hiebsch (1987), respectively as described below.

LER = La + Lb = Yab/ Yaa + Yba/Ybb

Where La and Lb are the LERs for the individual crops of the system

Yab = Intercrop yield of crop ‘a’
Yba = Intercrop yield of crop ‘b’
Yaa = Pure stand crop yield of ‘a’
Ybb = Pure stand crop yield of ‘b’

ATER = (Ryc x tc) x (Ryp x tp)/T

Where

Ryc = Relative yield of crop c (main crop)
Ryp = Relative yield of crop p (intercrop)
tc = Growth duration (days) for crop ‘c’
 tp = Growth duration (days) for crop ‘p’
T = Growth duration (days) for the whole system

Economic benefits of maize basil intercropping and N fertilization were determined by calculating monetary advantage index (MAI) and marginal analysis using formula established by Willey (1979) and CIMMYT (1988), respectively. Prevailing local market prices of maize and basil were taken for economic analysis and the prices of maize and basil were 5 and 32 ETB/Ethiopian Birr), respectively, during the experiment.

MAI = (Value of combined intercrops) x (LER-1)/LER

Where MAI = Monetary advantage index
LER = Land equivalent ratio

RESULTS

None of the parameters which were measured under this experiment was significantly affected by the interaction effect of cropping pattern and fertilizer treatments.

Effect of cropping pattern

Maize

Among all measured parameters of maize, only plant height, biological yield and 1000 seed weight were significantly affected by spatial arrangement (Table 2). Planting maize at 1:3 row arrangement produced the lowest significant value of plant height (204.0cm),
biological yield (70.80 q ha⁻¹) and 1000 seed weight (236.65g). On the other hand, non-significant variation was observed in biological yield between sole planting and 1:1 row ratio whereas 1:2 and 1:3 row ratios gave non-significant variation in biological yield. Similarly, the effect of 1:1 and 1:2 ratios was not significantly different from the sole planting of maize for plant height and 1000 seed weight (Table 2). Even statistically not significant, 1:1, 1:2 and 1:3 spatial arrangement resulted in 2.36%, 7.67% and 10.63% reduction in yield of maize, respectively, when compared with sole planting (30.47 qha⁻¹).

Basil

Regarding basil, all parameters were significantly influenced by spatial arrangement (Table 3). The values of biological yield and herbal yield were not significantly varied under sole planting and 1:1 row arrangement. Similarly, the variations in the number of branches per plant under sole planting, 1:1 and 1:2 row arrangements were not significantly different (Table 3). Generally, maximum significant values of number of branches (10.65), biological yield (963.48 kg ha⁻¹) and herbal yield (251.75 kg ha⁻¹) were recorded due to sole planting of basil whereas the minimum significant values of these parameters were obtained from 1:3 row arrangements (Table 3). In contrary, 2.16%, 6.62% and 8.91% increment in plant height was recorded due to 1:1, 1:2 and 1:3 spatial arrangements, respectively, over sole planting of basi.

Nitrogen effect

Maize

Nitrogen application significantly improved plant height, biological yield, 1000 seed weight and grain yield in maize (Table 4). Increasing nitrogen rate from 0 to 128kg ha⁻¹ significantly increased biological yield, 1000 seed weight and grain yield from 69.67q ha⁻¹, 233.83g, and 21.15q ha⁻¹ to 76.65 q ha⁻¹, 248.25g and 32.82q ha⁻¹, respectively. However, increasing nitrogen rate beyond 128kg ha⁻¹ did not show any significant effect on these parameters (Table 4). Similarly, no significant variation was observed in plant height from application of nitrogen above 92 q ha⁻¹. However, no significant variation was recorded in number of cobs per plant, number of kernel rows per cob and number kernels per row.

Basil

Regarding basil, all parameters which were measured under this study were significantly improved by fertilizer treatment (Table 5). Similar to maize, increasing fertilizer
rate from 0 to 128 kg ha\(^{-1}\) was observed to substantially improved plant height, branch number, biological yield and herbal yield from 39.72cm, 7.42, 463.9 kg ha\(^{-1}\) and 119.25 kg ha\(^{-1}\) to 45.5, 10.57, 1002.97 kg ha\(^{-1}\) and 263.25 kg ha\(^{-1}\), respectively, whereas applying fertilizer beyond this rate did not show any significant effect on these parameters (Table 5).

**Productivity, area time equivalent ratio (ATER) and monetary advantage (MAI)**

Land equivalent ration (LER) was used to evaluate the productivity of intercropping patterns. It an indicator for the presence and lack of yield advantages in intercropping whenever its values are greater than one and less than or equal to one, respectively. Data on LER of all intercropping treatments showed that values of LER were greater than one (Table 6). 98%, 70% and 50% yield advantages were obtained from 1:1, 1:2 and 1:3 spatial arrangements, respectively, over sole cropping system (Table 6).

ATER provided a more realistic comparison of the yield advantage of intercropping over that of sole cropping as it considers variations in time taken by the component crops of different intercropping systems. ATER values for each maize basil intercropping system were greater than one (Table 6). 1:1 and 1:3 spatial arrangements gave the highest (1.62) and the lowest (1.27) ATER values, respectively. The different spatial arrangement gave higher values of MAI in this experiment (Table 6). The highest value of MAI was obtained from 1:1 spatial arrangement (11373.44) followed by 1:2 (8383.94) while the least value (6157) was recorded due to 1:3 spatial arrangement.

**Economic analysis**

Economic analysis showed that all fertilizer treatments
Table 7: Effect of nitrogen application on dominance and marginal analysis

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Gross benefit (ETBha(^{-1}))</th>
<th>Total cost that vary (ETBha(^{-1}))</th>
<th>Net benefits (ETBha(^{-1}))</th>
<th>Marginal costs (ETBha(^{-1}))</th>
<th>Marginal net benefits (ETBha(^{-1}))</th>
<th>Marginal rate of return %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 kg Nha(^{-1})</td>
<td>14391</td>
<td>14391</td>
<td>14391</td>
<td>19549</td>
<td>5158</td>
<td>247.98</td>
</tr>
<tr>
<td>92 kg Nha(^{-1})</td>
<td>21629</td>
<td>2080</td>
<td>2080</td>
<td>2080</td>
<td>19549</td>
<td>247.98</td>
</tr>
<tr>
<td>128 kg Nha(^{-1})</td>
<td>24834</td>
<td>2863</td>
<td>21971</td>
<td>783</td>
<td>24422</td>
<td>3119.03</td>
</tr>
<tr>
<td>164 kg Nha(^{-1})</td>
<td>24238</td>
<td>3645</td>
<td>20593</td>
<td>782</td>
<td>-</td>
<td>Dominated</td>
</tr>
</tbody>
</table>

Table 8 (a): Correlation between traits (Maize)

<table>
<thead>
<tr>
<th>PHT</th>
<th>NCOBPP</th>
<th>RPCOB</th>
<th>KPROW</th>
<th>TWS</th>
<th>BY</th>
<th>SY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHT</td>
<td>0.648**</td>
<td>0.699**</td>
<td>0.778***</td>
<td>0.926***</td>
<td>0.856***</td>
<td>0.813***</td>
</tr>
<tr>
<td>NCOBPP</td>
<td>0.563*</td>
<td>0.605*</td>
<td>0.706**</td>
<td>0.719**</td>
<td>0.681**</td>
<td></td>
</tr>
<tr>
<td>RPCOB</td>
<td>0.698**</td>
<td>0.704**</td>
<td>0.755***</td>
<td>0.725**</td>
<td>0.479*</td>
<td></td>
</tr>
<tr>
<td>KPROW</td>
<td>0.813***</td>
<td>0.847***</td>
<td>0.725**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSW</td>
<td>0.973***</td>
<td>0.926***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DY</td>
<td></td>
<td>0.93***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SY</td>
<td></td>
<td>0.899***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: PHT; plant height, NCOBPP; number of cobs per plant, RPCOB; number of rows per cob, KPROW; kernel per row, TSW; thousand seed weight, BY; biological yield, SY; seed yield; ns, ***, ** and * denote nonsignificant, significant at P ≤0.001, 0.01 and 0.05 levels, respectively.

Table 8 (a): Correlation between traits (Basil)

<table>
<thead>
<tr>
<th>Plant height</th>
<th>Branch number</th>
<th>Biological yield</th>
<th>Herbal yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant height</td>
<td>0.21ns</td>
<td>0.33ns</td>
<td>0.33ns</td>
</tr>
<tr>
<td>Branch number</td>
<td>0.93***</td>
<td>0.93***</td>
<td></td>
</tr>
<tr>
<td>Biological yield</td>
<td>0.93***</td>
<td>0.99**</td>
<td></td>
</tr>
<tr>
<td>Fruit yield</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: **, *** and ns denote significant differences at P ≤0.01, P ≤0.001 and none significant, respectively.

resulted in higher net benefits where the minimum (14391 ETBha\(^{-1}\)) and maximum values (21971 ETBha\(^{-1}\)) were recorded due to 0 kg Nha\(^{-1}\) and 128 kg Nha\(^{-1}\), respectively (Table 7). Similarly, marginal analysis showed that application of nitrogen at the rate of 128 kg Nha\(^{-1}\) produced the highest value of marginal rate of return (3119.03%) followed by 92 kg Nha\(^{-1}\) (247.98%) treatment. However, applying nitrogen beyond 128 kg Nha\(^{-1}\) was observed to be uneconomical (Table 7).

DISCUSSION

Cropping system

Lack of substantial variation between the effects of sole planting and 1:1 row arrangement on all parameters for component crops might be attributed to lower inter and intra-specific competition due to the lower population density at 1:1 row ratio which might have provided a better soil resource condition with higher light availability for basil plants to grow vigorously (Tamiru, 2014). The significant reduction in plant height, biological yield and 1000 seed weight of maize due to 1:3 planting arrangement could be associated with higher competition for soil resources or allelopathic effect as basil population increased in intercrop with maize Olowe and Adeyemo (2009).

Similarly, the significant decrement in branch number, biological yield and herbal yield of basil with increasing basil population in intercrop might also due to increment in competition for soil resources (Morgado and Willey, 2008). On the other hand, the significant increase in plant height with increasing basil population in intercrop could be attributed to higher shading effect of maize.

Fertilizer effect

The significant improvement in plant height and biological
yield of basil and maize crops due to fertilizer treatment might be associated with development of larger plants with extensive root system capable of supplying increased water and nutrient demand of the plants (Boquet and Breitenbeck, 2000). Evans and Edwards (2001) also observed that N nutrition enabled greater leaf area production, which resulted in greater light interception and transpiration, thereby increasing dry matter accumulation.

Nitrogen fertilization substantially improved 1000 seed weight of maize which is in agreement with the findings of Chaturvedi (2005) who explained the role of nitrogen in maturation, flowering and fruiting, including seed formation. Increasing levels of nitrogen were observed to significantly improve branch number in basil which is in line with the work of Samuelson and Larson (1993). The lack of significant improvement in the measured parameters of maize and basil by applying nitrogen level beyond 128 Nkg ha$^{-1}$ might be ascribed to enhanced the formation of proteins from carbohydrates, which is the result of photosynthesis, resulting in more protoplasm and succulent plants (Havlin et al., 1999) and thereby reduced dry matter.

Correlation analysis indicated that grain yield of maize showed significant and positive relationship with all parameters which were measured under this study for the crop (Table 8a). This could indicate that the overall improvement in grain yield of maize with fertilizer application might be due to improvement in these parameters in response to fertilizer treatments. Herbal yield of basil also showed significant and positive relationship with branch number and biological yield (Table 8b) indicating that the improvement in branch number and biological yield due to nitrogen rates contributed for substantial increase in herbal yield.

**Productivity and profitability analysis**

Higher productivity of intercrop components was observed in this experiment than sole components as revealed by higher land equivalent ratios greater than or equal to 1.50 which could be attributed to better utilization of resources by the intercrop components than monoculture (Sobkowicz, 2006). ATER values in maize basil intercropping systems were smaller than LER indicating the removal of the over estimation of resource utilization.

Monetary value index is an indicator of economic feasibility intercropping systems as compared to sole cropping (Aesim et al., 2008). Therefore, the positive values of monetary value index showed a definite yield advantage of maize basil intercropping as compared to sole components. A probable reason for this could be better utilization of resources between maize and basil intercropping arrangements. Additionally, the highest value of land equivalent ratio (1.98) which was observed to be associated the maximum monetary advantage index MAI (11373.44) as reported by Ghosh (2004). From marginal analysis, applying above 128 kg Nha$^{-1}$ was not economical which could be either due to higher cost and relatively less net benefit to compensate for respective increment in the cost of fertilizer rate.

**CONCLUSION AND RECOMMENDATION**

Generally, the result of this study showed that intercropping maize with basil at 1:1 spatial arrangement with application of 128 kg Nha$^{-1}$ could provide farmers with the best yield advantage and income over sole planting of component crops. However, in order to come up with sound conclusion, the study must be repeated replicated over seasons and locations.

**REFERENCES**


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